Monitoring populations of Heath Frog *Litoria littlejohni* in the Shoalhaven region on the south coast of New South Wales

Garry Daly[1] **and Philip Craven**[2]

[1] PO Box 3109, North Nowra 2541
[2] Department of Environment and Climate Change PO Box 707, Nowra 2541
Email for corresponding author: gaiaresearch@shoalhaven.net.au

ABSTRACT

We monitored populations of the Heath Frog *Litoria littlejohni* in conservation reserves near Nowra on the south coast of New South Wales. Thirteen 250 m transects located along perennial creeks were surveyed at night once a year for 30 minutes each from 2001 to 2006. The sites covered a range of altitudes and vegetation communities and were surveyed between late August and October. The area has a relatively high population density of *L. littlejohni*, with animals being detected at 12 of the 13 sites. A period of below average rainfall overlapped the census period from 2002 to 2006 and a wild fire in January 2002 burnt 12 of the study sites. The number of frogs detected after the fire declined from 100 to 46. Subsequent surveys found that the population recovered but not to pre-fire densities.

Breeding was evident during each survey by the presence of amplecting frogs, eggs and/or recently hatched tadpoles. Larger tadpoles possibly from the previous year's breeding were detected at some sites. One amplexed pair was retained and laid a total of 194 eggs, which hatched 10-12 days later. The reproductive effort (clutch mass divided by female post partum mass) was 0.34. No *L. littlejohni* were detected below 130 metres elevation. In 2005 the Plague Minnow *Gambusia holbrooki* was found at one site and in 2006 the Yabbie *Cherax destructor*was found at another site. Predation of eggs and tadpoles from these introduced species may impact on the population of Heath Frog.

Key words: *Litoria littlejohni,* monitoring populations, wildfire, Morton National Park, Parma Creek Nature Reserve, Jerrawangala National Park.

Introduction

The Heath Frog *Litoria littlejohni* was described in 1980 (White *et al.* 1994), however since that time very little information has been published on the species biology. Lemckert (2004) states that as of 2001, only 21 sites were recorded for this species on the National Parks and Wildlife Service (NPWS) Atlas of New South Wales Wildlife, the smallest number of records for an amphibian in the region. The range of the species extends from the Watagan State Forest (Mahony 1993) south to Buchan in north-eastern Victoria (Anstis 2002), an approximate area of 65,200 square km (Hero *et al.* 2002). *Litoria littlejohni* has a patchy distribution within NSW and populations are confined to areas between 100 and 950 metres above sea level (a.s.l.) (Ehmann 1997). *Litoria littlejohni* was listed on schedule 2 of the New South Wales *Threatened Species Conservation Act (1995)* as vulnerable in June 2000 because there were few known populations with few individuals. The species is currently listed nationally as vulnerable on the schedules of the *Environment Protection and Biodiversity Conservation Act 1999*.

The population ecology of Australian amphibians has only recently received attention with most studies concentrating on species in decline (Richards *et al.* 1993; Gillespie and Hollis 1996; White and Pyke 1996; Goldingay and Newell 2005). Broad scale systematic surveys for amphibians are also a relatively recent phenomenon and there have been few studies that utilise systematic surveys to provide quantitative data on a range of lotic frog species (Daly *et al.* 2002; Daly 2006). Rapid declines in some species of amphibian underline the need to conduct long-term systematic monitoring of specific populations. Unfortunately, even though many species of frog are in decline, data on their basic ecology are still rudimentary.

Litoria littlejohni is rarely detected and it has been recorded as having an unpredictable calling activity (Lemckert 2004). There are conflicting statements on the species breeding habitat with some authors stating that the species does not breed in streams (Hero *et al.* 1991). Anstis (2002) states that breeding occurs in permanent and semipermanent dams and ponds. Lemckert (2004) found that the number of calling male *L. littlejohni* at known sites was small, with 81% (N = 47) of records being for four or fewer animals. In view of the paucity of information on the species' population ecology, we surveyed the adult population of *L. littlejohni* in Morton National Park (NP), Parma Creek Nature Reserve and Jerrawangala NP from 2001 to 2006 with the aim of quantifying changes in the population over time. Other aspects of the breeding biology were investigated to produce more information on the species biology and ecology.

Methods

Study sites

Surveys for *L. littlejohni* were conducted in Morton NP (196065 ha), Parma Creek Nature Reserve (3531 ha) and Jerrawangala NP (4029 ha), some 15 kilometres to the south-west of Nowra on the south coast of NSW. Although the conservation areas surveyed are given separate titles they form a near contiguous (fragmented by gravel roads) block of bushland.Thirteen sites were surveyed. The sites covered a range of altitudes (90 to 640 m a.s.l.) and vegetation types (Table 1). Access to sites was a selection criterion and hence most were located upstream or downstream of narrow formed trails. Most sites were separated in distance by at least one kilometre; the exceptions were two sites (Parma Creek c and d) located upstream and downstream of trail creek crossings. To avoid the possibility of double counting frogs, these sites were surveyed sequentially on any given night. A total of 13 sites was selected for survey. Logistically, this number of sites could be surveyed sequentially over about 3-4 nights each year. The majority of sites were chosen because previous surveys in the region (Daly 2006) indicated the presence of *L. littlejohni* (based on the morphology of tadpoles and detections of adult frogs). However, systematic sampling had not been undertaken at any of these sites. The survey period (August to October) was selected because previous targeted searches indicated reproductive activity of *L. littlejohni* was high during spring.

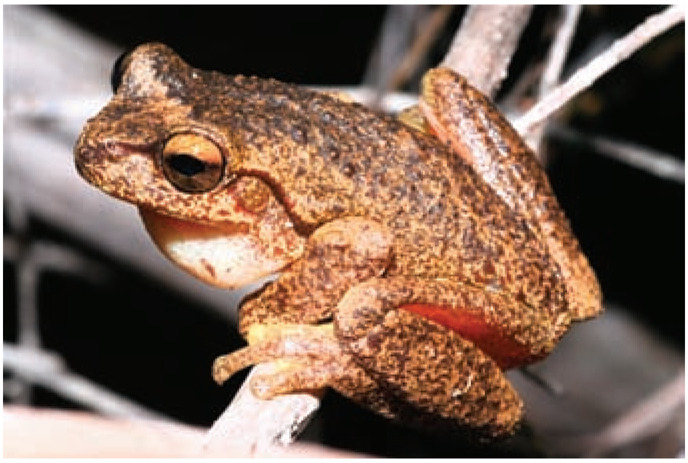

Figure1. Male *Litoria littlejohni* Flat Rock Creek. Photo G. Daly

Habitat

Survey sites were located beside the upper laterals of second and third order perennial creeks. The geological formation was Nowra Sandstone and at most sites the habitat within the immediate area of the creek varied from narrow races of water on exposed potholed bedrock to sandy ponds (up to 2 m deep) with ribbon weed *Vallisneria gigantea*. The water turbidity varied in quality between sites from clear to tannin stained.

The immediate vegetation beside the creeks was primarily woodland (to 15 m in height), which had a thick shrublayer of heath species (Table 1). Thomas *et al.* (2000) describe the vegetation as forest ecosystems 137, 138 and 139. Tindall *et al.* (2005) describe the vegetation as forest types 148 and 122. In general the surrounding country was relatively flat, the exceptions were Gnatilia Creek and Boolijah Creek, which had deeper gullies and tall open forest. However, even these sites were adjacent to woodland and heath. The vegetation of the general area is described by Thomas *et al.* (2000) as forest ecosystems 137, 138 and 139. Details of location, morphology, vegetation, and fluvial components of sites were recorded.

Frog survey

A single count was conducted each year at each of the 13 survey sites in 2001, 2002, 2003, 2005 and 2006 from late August to October (Table 2). Most searches were conducted during September, and those conducted during October were as a consequence of access problems associated with post windstorm debris covering the roads. Nocturnal searches involved spotlighting approximately 250 m of creek for 30 minutes per transect. If two people

Table 1. Description of vegetation and location of survey sites.

Site Name	Easting	Northing	Alt	Vegetation beside creek
Flat Rock Creek	271000	6119900	180	*Eucalyptus sclerophylla, Banksia ericifolia.*
Bollerang Ck	271500	6118200	160	*E. sclerophylla, B. ericifolia.*
Parma Creek a	274500	6124600	90	*E. sclerophylla, B. ericifolia.*
Parma Creek b	273100	6124700	130	*E. sclerophylla, B. ericifolia.*
Rixon Creek	253300	6102800	640	*E. piperita, E. sclerophylla, Melaleuca squarrosa.*
unnamed creek	253900	6104400	640	*E. piperita, M. squarrosa, B. ericifolia, Hakea dactyloides.*
Tianjara Creek a	255200	6105900	600	*E. piperita, M. squarrosa, Gleichenia spp.*
Boolijah Creek	254000	6110600	540	*E. piperita, Acacia meansii.*
Tianjara Creek b	256650	6111100	500	*E. piperita, Kunzea ambigua, B. ericifolia, Leptospermum spp.*
Parma Creek c	271150	6121600	170	*E. sclerophylla, B. ericifolia.*
Parma Creek d	271300	6121600	160	*E. sclerophylla, E. punctata, B. ericifolia.*
Gnatilia Creek	262000	6114100	370	*E. piperita, Syncarpia glomulifera, Callicoma serratifolia.*
Boolijong Ck	264700	6118200	310	*E. piperita, C. serratifolia, M. leneariifolia, B. ericifolia.*

Suffix a-d represents different sites along the same creekline. Grid references in UTM Zone 56 AMG 66 co-ordinates. Altitude (Alt) in metres above sea level. Eastings and northings in ADG Z56.

Table 2. Time when each site surveyed (EST) in the various years.

Site	2001 survey	2002 survey	2003 survey	2005 survey	2006
Flat Rock Creek	18.53-19.23 on 3.9.01	18.53-19.23 on 3.9.02	19.00-19.30 on 8.9.03	18.35-19.05 on 1.9.05	19.40-20.10 on 3.9.06
Bollerang Ck	20.20-20.50 on 3.9.01	21.50-22.20 on 4.9.02	18.16-18.46 on 8.9.03	18.57-19.27 on 21.9.05	18.18-1848 on3.9.06
Parma Creek a	22.00-22.30 on 3.9.01	22.00-22.30 on 3.9.02	18.21-18.51 on 18.9.03	20.10-20.40 on 22.9.05	19.19-1959 on18.9.06
Parma Creek b	23.15-23.45 on 3.9.01	21.50-22.20 on 5.9.02	21.10-21.40 on 18.9.03	20.50-21.20 on 22.9.05	18.23-18.53 on 18.9.06
Rixon Creek	19.15-19.45 on 4.9.01	18.35-19.05 on 4.9.02	18.51-19.21 on 15.10.03	18.45-19.15 on 30.9.05	20.29-1959 on 20.9.06
unnamed creek	20.31-21.01 on 4.9.01	19.20-19.50 on 4.9.02	19.37-20.07 on 15.10.03	19.37-20.07 on 30.9.05	19.37-20.07 on 20.9.06
Tianjara Creek	21.55-22.25 on 4.9.01	20.23-20.53 on 4.9.02	18.30-19.00 on 9.9.03	20.40-21.10 on 30.9.05	18.43-19.13 on 19.9.06
Boolijah Creek	18.24-18.54 on 5.9.01	18.25-18.55 on 5.9.02	20.24-20.54 on 9.9.03	18.27-18.57 on 23.9.05	21.11-21.41 on 19.9.06
Tianjara Creek	19.40-20.10 on 5.9.01	19.15-19.45 on 5.9.02	19.38-20.08 on 28.8.03	18.20-18.50 on 23.9.05	20.03-20.33 on 19.9.06
Parma Creek c	21.04-21.34 on 5.9.01	18.20-18.50 on 25.9.02	19.53-20.23 on 8.9.03	18.30-19.00 on 22.9.05	20.42-21.12 on 18.9.06
Parma Creek d	21.50-22.20 on 5.9.01	18.57-19.27 on 25.9.02	20.32-21.03 on 8.9.03	19.10-19.40 on 22.9.05	21.22-21.52 on 18.9.06
Gnatilia Creek	18.56-19.26 on 6.9.01	22.32-22.02 on 28.8.02	18.24-18.54 on 10.9.03	19.48-20.18 on 23.9.05	18.31-19.01 on 21.9.06
Boolijong Ck	21.03-21.33 on 6.9.01	20.25-20.55 on 5.9.02	19.45-20.15 on 10.9.03	22.00-22.50 on 22.9.05	20.05-20.35 on 21.9.06

walked the same transect only one person recorded detections, the other assisted in observations and occupational health and safety requirements.Fifty watt/12 volt Spotlights(50 W, 12 V) were used to observe frogs, tadpoles and spawn. Surveys were conducted between dusk and 23.45 Eastern Standard Time. The temperatures, during the surveys ranged between 5.8-15.7^{O} C (air) and 8.1-19°C (water). The NSW NPWS hygiene protocol for frogs (2001) was followed.

The survey period coincided with extreme variation in rainfall, with below average rain from 2002-2006 (Table 6).During the survey period the Department of Primary Industries had declared the area in drought for periods in 2002, 2003 and 2004. Surveys were generally conducted independently of rainfall events.

In general frogs were detected by recognition of species-specific calls.Animals were recorded as being female based on position while in amplexus and or their larger snout-vent length (Barker *et al.*1995). The total number of frogs recorded at a site was a tally of the number of calling males (a subset of these were observed) plus females (or subadult in one instance).Generally frogs were not handled, however one amplexed pair was captured and retained overnight to determine clutch size and other reproductive data.

Results

Effect of altitude, fire and rainfall on heath frogs

Litoria littlejohni (Figure 1) was detected at 12 of the 13 sites at altitudes that ranged from 130-640 m a.s.l. (average 366 m a.s.l.).The species was absent from the site that had an altitude of 90 m a.s.l.. The total number of frogs found during one survey 'round' ranged from 46-100 animals. The greatest number was detected in 2001, prior to a wildfire (January 2002) and the lowest in the following year (post fire).Table 3 shows the number of frogs counted at each site in each year. The number of frogs detected rose in 2003, 2005 and 2006, but not to the density detected before the fire (Table 3). A repeated measures analysis of variance of square-root transformed *L. littlejohni* counts confirmed a significant difference across years ($F_{4,48}$=5.82, P<0.001). A *post-hoc* Dunnett's test found that the first year count ("control") was greater than in each subsequent year. One site (Tianjara Creek b) was not burnt during the 2002 fire. The number of *L. littlejohni* detected at this site also fell in 2002 and 2003 but was near pr-fire levels in 2005 and 2006.

Rain prior to the surveys may have had a relationship with frog activity (Table 6). The highest number of frogs recorded was in 2001 when 80 mm of rain fell during August. This can be compared to 10 mm in 2002, 33 in 2003, 4 in 2005 and 38 in 2006. The lowest numbers of frogs were detected in 2002 when only 11 millimetres of rain fell during September. This can be compared to 33 mm in 2001, 12 in 2003, 57 in 2005 and 56 in 2006. The temperature at which the surveys were conducted was fairly consistent at the sites over the years and surveys were generally undertaken at times when there was little cloud cover and no significant rainfall events.

Table 3. Number of heath frogs detected (excluding tadpoles).

Site	2001	2002	2003	2005	2006	Site total
Flat Rock Creek	13	3	8	4	9	37
Bollerang Ck	8	4	4	4 (1)	5	25
Parma Creek a	0	0	0	0	0	0
Parma Creek b	9	1	1	6	4	21
Rixon Creek	6	8	7	10	10	41
unnamed creek	6 (1)	5	9	5	17	42
Tianjara Creek a	9	10 (1)	6	7	8	40
Boolijah Creek	2	0	0	1	0	3
Tianjara Creek b	15 (1)	6	9	14	12(2)	56
Parma Creek c	9	2	7	2	1	21
Parma Creek d	9 (1)	2	4	2	2	19
Gnatilia Creek	7	2	1	1	2	13
Boolijong Ck	7	3	2	6 (2)	3	21
Total for year	**100**	**46**	**58**	**62**	**73**	**339**
Average + (SE)	7.7 (1.09)	3.5 (0.83)	4.5 (0.94)	4.8 (1.14)	5.6 (1.45)	

Number in brackets indicates females

Reproductive activity of heath frogs

Litoria littlejohni was detected calling and breeding in second and third order perennial streams. Apart from those in amplexus, all males observed (N = 84) were perched on branches near or above pools. Although no quantitative assessment was made, the majority of these branches were dead. The pools ranged in size and depth from approximately 3 x 1 x 0.3 m deep to 25 x 5 x1.4 m deep. Males were more commonly detected than females at a ratio of 47:1.

The senior author has extensive experience in the identification of spawn and tadpoles of amphibians within this region (see Anstis 2002). Spawn and recently hatched tadpoles were observed at many sites in each year that the surveys were conducted (Table 4). The number of sites at which breeding (spawn/tadpoles) occurred ranged from eight in 2001 to five in 2002. Eggs were primarily attached to small twigs on the distal ends of partially submerged dead branches. In one instance eggs were located on ribbonweed. The eggs were laid along the twigs approximately 100 - 300 mm below the surface of the water. Hatched tadpoles were observed to feed on the jelly capsules of egg clusters. Tadpoles were uniform black to grey and observed to inhabit the mid to upper levels of the water column. During the day large tadpoles (50 mm total length) were observed to school below the waters surface (Figure 2).

During the surveys, only one subadult frog was observed. Spawn and recently hatched tadpoles (i.e. approximately 25 mm in total length) were observed at some sites every year. Three amplecting pairs were observed, two of these were swimming mid-creek whereas the third was stationed on a rock in a seepage line. One amplexed pair was retained overnight in an inflated plastic clip seal bag with approximately 120 mm of water taken from the capture site. Several small sticks were placed in the bag to provide an appropriate substrate for oviposition. A total of 194 eggs was laid on 6 September 2001. Most eggs hatched 10-12 days later, however 46 failed to hatch. The clutch was broken into several groups of eggs. The male was 47 mm (snout to vent) and the female 60 mm (snout to vent). The gravid female weighed 16.8 g and 11.8 g after spawning. The reproductive effort (clutch mass divided by female post partum mass) was 0.34.

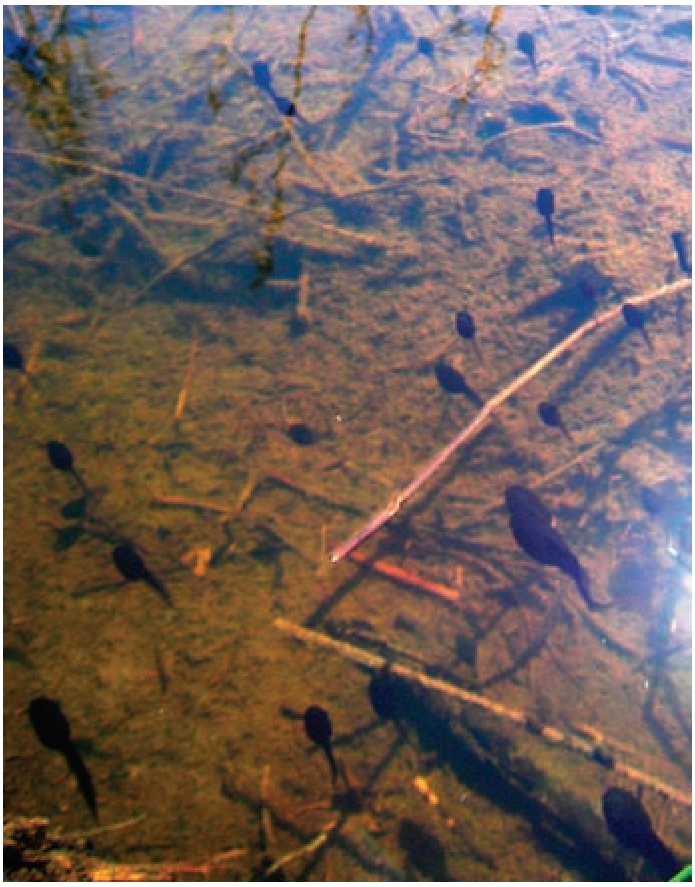

Figure 2. Schooling *Litoria littlejohni* tadpoles. Photo G Daly

Table 4. Reproductive activity of heath frogs.

Site Name	2001	2002	2003	2005	2006
Flat Rock Creek	t, s	n	t	s	t
Bollerang Ck	t, s	t	t	t	t
Parma Creek a	n	n	n	n	n
Parma Creek b	n	n	n	n	n
Rixon Creek	T, s	T	T	T	T
unnamed creek	a, T	T	t, s	T, t, s	T
Tianjara Creek a	T, s	a, T	s	t	T
Boolijah Creek	n	n	n	n	n
Tianjara Creek b	a, T	T	s	n	n
Parma Creek c	T, s	T, t	T, t	T, t	T, t
Parma Creek d	a, t, s	t	t	t	t
Gnatilia Creek	t, s	n	n	t	n
Boolijong Ck	T,s	s	T	s	T

a = amplecting frogs observed; t = recently hatched tadpoles observed; T = large (> 40 mm total length) tadpoles of observed, s = spawn observed. n = no reproductive activity observed

Other species of frog detected during surveys

Thirteen other species of frog were detected during the surveys. These were the Blue Mountains Tree Frog *Litoria citropa*, Jervis Bay Tree Frog *Litoria jervisiensis,* Lesueur's Tree Frog *L. lesueuri*, Southern Leaf Green Tree Frog *Litoria nudidigita,* Peron's Tree Frog *Litoria peroni*, Verreaux's Tree Frog *Litoria verreauxii,* Common Eastern Froglet *Crinia signifera,* Giant Burrowing Frog *Heleioporus australiacus* (tadpoles), Haswell's Frog *Paracrinia haswelli*, Pobblebonk *Limnodynastes dumerilii* (tadpole at one site), Striped Marsh Frog *Limnodynastes peroni*, Bibron's Toadlet *Pseudophryne bibronii* and Tyler's Toadlet *Uperoleia tyleri* (as tadpoles).

The most abundant species were *Crinia signifera* and *Paracrinia haswelli* (Table 5). The most common tree frog was *Litoria littlejohni* with 339 detected. *Litoria citropa* and *Litoria lesueuri* were also common with 229 and 130 animals found, respectively.Comparative annual total of these species are given (Table 5). The minimum total number of all species was in 2002, after the fire. Thereafter (except *C. signifera*) the total number detected increased in 2003 and 2005 but fell in 2006. There was a large variance in the number of *Litoria citropa* and *Litoria lesueuri* detected over the survey. Relatively few females were observed, the majority being in amplexus.

The diversity of amphibians at sites ranged from 4-8 species. The sites where the highest numbers of frogs were detected were at relatively low altitude and had large expanses of potholed exposed sandstone. *Litoria citropa*, *L. lesueuri* and *C. signifera* were most abundant at these sites and amplexed pairs and eggs of these species were found. *Litoria nudidigita* was primarily found at sites that, had a dense canopy and shrublayer of Matrush *Lomandra longifolia* and Fishbone Water Fern *Blechnum nudum. Paracrinia haswelli* was most abundant beside large deep pools. *Litoria citropa* and *L. lesueuri* were only observed in association with areas of exposed sandstone. *Litoria citropa* were observed calling while stationed on rocks and branches, whereas *L. lesueuri* was only observed on or adjacent to exposed sandstone. The other species of frog were detected at such low frequencies that no definite associations with habitat could be described.

Spatial segregation was also observed between *L. citropa*, *L. lesueuri* and *L. littlejohni*. *Litoria littlejohni* oviposited on twigs in still pools whereas *L. citropa* and *L. lesueuri* laid their eggs in the shallows on flat sandstone shelves. Segregation was also observed in the tadpoles of these species with *L. citropa* and *L. lesueuri* being benthic whereas *L. littlejohni* was frequently observed to float and swim in the water column. An indication of temporal separation of breeding was observed. Amplecting *L. citropa* and *L. lesueuri* and their eggs were observed during the surveys whereas recently hatched *L. littlejohni* tadpoles and eggs were observed.

Table 5. Annual total number of the most abundant five species of frog detected.

Species	2001	2002	2003	2005	2006	Total
Litoria citropa	2	23 (3)	32	113 (1)	59 (2)	229
Litoria lesueuri	5 (1)	15	19	61 (3)	30	130
Litoria littlejohni	100 (3)	46 (1)	58	62 (3)	73 (2)	339
Crinia signifera	63	38 (1)	131 (1)	98	151 (1)	481
Paracrinia haswelli	89	50	75	96	69	379

Number in brackets indicates females

Table 6. Monthly rainfall in millimetres recorded at Nowra during the survey period. (Nowra RAN Air Station AWS station 068072)

Month	2001	2002	2003	2004	2005	2006	Monthly totals
January	75	105	***46***	42	86	38	392
February	112	245	***121***	79	105	10	672
March	71	67	***77***	65	69	37	386
April	40	40	***93***	92	22	8	295
May	26	31	***230***	17	54	***39***	397
June	22	29	54	11	88	***154***	358
July	98	3	30	***45***	163	***81***	420
August	80	10	33	***20***	4	***38***	185
September	33	11	12	***57***	57	***56***	226
October	46	***7***	***87***	209	52		401
November	57	***2***	***130***	81	94		364
December	13	59	50	103	13		238
Annual totals	**673**	**609**	**963**	**821**	**807**		

Data courtesy Bureau of Meteorology.Note average for Nowra is 1153 mm. Months declared in drought by the Department of Primary Industries are shown in italics.

Discussion

Variation in population counts

The survey recorded 339 *L. littlejohni* at 12 sites over five years with a survey effort of 6.5hrs per annum. At five sites, ten or more adult frogs were recorded during a single 30 minute census.Based on previous records (Ehmann 1997; Lemckert 2004, DEC 2005, Daly unpub. data) the study area has the largest population of *L. littlejohni* currently known. The only area that has a similar known population density is Barren Grounds NR/Budderoo NP (Neilly2001) in the southern highlands near Robertson.

The total number of *L. littlejohni* detected during the 2002survey was about half of that detected during 2001, thereafter there was an increase in the number detected. However, over the survey period the total number did not attain that recorded pre-fire.The variation may be a result of fire and/or the prolonged dry period, although it is not possible to determine the impact of each factor. Long term surveys and appropriate controls are required to elucidate the role of each of these factors on the populations, while population estimates with small standard errors are needed to determine the real extent of any decline.

An important finding was that wildfire (intense at some sites) did not eliminate populations of frogs and this raises the question: where do *Litoria littlejohni* (and the other species) seek refuge at the time of fire?

Fire had an indirect impact on some creeks by reducing vegetation cover and increasing the vulnerability of soil to erosion.Some breeding ponds were partially filled with sand and reproduction was not observed at some of these sites post fire.Other studies have suggested that disturbances such as timber harvesting and road construction can impact on lotic species of frog (Gillespie and Hollis 1996, Gillespie 2002). Alterations such as increased bedload post- fire may only last a few years as the regenerating vegetation stabilised the creek banks.Although the number of survey sites and controls were not adequate to provide a statistically significantmeasure on declines related to fire, the impact was notable and fire frequency may be an issue for the sustainable management of *L. littlejohni*.

The detection in 2005 of *Gambusia holbrooki* at one site and *Cherax destructor* in 2006 at another will further complicate the issue of assessing the impact of fire and drought as numbers of adult *L. littlejohni* would be expected to decline as a result of reduced recruitment from the tadpole stage (Morgan and Buttemer 1996).In surveys in another portion of Parma Creek catchment there was a very high density of *C. destructor.* At this site no endemic *Euastacus* species of yabbie or tadpoles were found to co-exist with *Cherax* (Daly unpub data). *Cherax destructor* has a natural distribution in NSW west of the divide (Jones and Morgan 2002) and east coast amphibians may not be able to co-exist with this species. So far *C. destructor* has colonised at least15 kilometres of the Parma Creek catchment. This species will spread to other areas as it is legally sold for aquaculture and pets (Figure 3). Predation of tadpoles and eggs by non-endemic *C. destructor* east of the Great Dividing Range may be considered as a threatening process to amphibians.

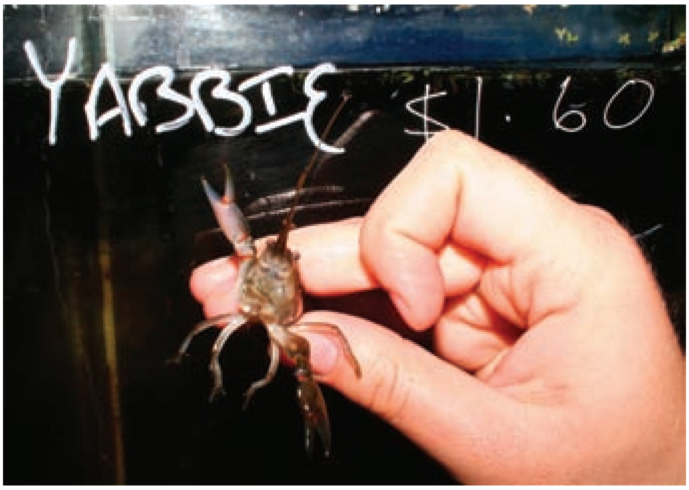

Figure 3. *Cherax destructor* for sale in a local pet shop. Photo G Daly.

Reproduction and habitat preference

Litoria littlejohni was detected in heath, woodland and tall open forest in areas of relatively low topographic relief on sandstone. The position of calling males, spawn and recently hatched tadpoles indicated that breeding is strongly associated with partially submerged fallen dead shrubs and branches that overhang slow-flowing pools in perennial second and third order streams above 130 m a.s.l.. These features were patchy in distribution along the streams surveyed and hence the distribution of frogs mirrored the distribution of these habitat components. Fallen dead shrubs are an important habitat component for *L. littlejohni* and are temporary, being washed away by flood events or natural decay. A fire frequency that is too frequent may reduce the availability of this habitat. Fire management plans are in preparation for reserves in which the study sites are located. Future assessment will be required to monitor sediment and the impact it has on the sites used by *L. littlejohni* for reproduction.

The observations presented here represent only a portion of the species breeding habitat utilised by *L. littlejohni*. Tadpoles have been observed in a range of other habitats such as isolated shallow, ephemeral pools (sediment control basins) and road dish drains (G. Daly pers. obs., Lemckert 2004). The species has been recorded breeding at various times of the year, for example in late spring at Barren Grounds NR (590 m a.s.l.) and autumn at the Watagan State Forest (Daly unpub data).

Prior to this study the clutch size of *L. littlejohni* had not been recorded. The observation in captivity of 194 eggs broken into several clumps is consistent with field observations of several clumps laid on twigs close together. Anstis (2002) states that clusters of up to 60 eggs are attached to submerged twigs, which confirms the observations here that clutches are laid in several clumps. In comparison to other species of native tree frog, *L. littlejohni* has a relatively low number of eggs per clutch (Tyler 1989; Anstis 2002).

Species segregation

Litoria littlejohni was sympatric with several species of lotic frog, namely *L. citropa*, *L. lesueuri* and *L. nudidigitus.* Breeding activity of the first three species (amplexed animals and spawn) was observed at several sites in each year and there was temporal and spatial segregation of these species in relation to sites utilised for calling, oviposition and the foraging behaviour of their tadpoles. Although eggs and amplexed *L. littlejohni* were found during the survey, there were relatively few observations of spawn and or amplexed *L. citropa* and *L. lesueuri*. *Litoria littlejohni* was found to breed prior to the other stream breeders. The ability of *L. littlejohni* to breed during late winter early spring gives its tadpoles the advantage of reduced competition with sympatric lotic species of frog.

Conclusions

This study demonstrates that surveys utilising fixed time/length streamside transects provide data that can quantify changes in abundance. However, additional work is necessary before any definitive conclusion can be made about changes to population densities in relation to fire, drought and invasive species. Within the Shoalhaven region,late winter and early spring are appropriate times to sample populations of *L. littlejohni* that utilise creeks for breeding as this period coincides with a high level of reproductive activity.

Acknowledgments

We thank B. Gray, R. Hall, A. Parsons, R. Phelps and M. Schulz for their assistance in the field. Rainfall data was supplied by the Bureau of Meteorology and drought declaration by the Department of Primary Industries. Two anonymous referees kindly reviewed the manuscript. Work was conducted under Scientific Licence S10470 and S11021. The work was partially funded and supported by the DECC South Coast Region, Ecologically Sustainable Forest Management Program.

References

Anstis, M. 2002. *Tadpoles of South-eastern Australia: A guide with keys.* Reed NewHolland, Sydney.

Barker, J., Grigg, G.C. and Tyler, M.J. 1995. *A Field Guide to Australian Frogs.* Surrey Beatty and Sons. Sydney.

Daly, G. 2006. Reptiles and amphibians of Morton National Park and environs on the south coast of New South Wales. *Herpetofauna* **36**: 5-24.

Daly, G, Pennay, P. and Coombes, D.2002. Surveys for the stuttering frog *Mixophyesbalbus* on the south coast of New South Wales. *Herpetofauna* **32:** 110-130.

DEC 2005. *Draft Terrestrial Vertebrate Fauna of the Greater Southern Sydney Region: Part 2 Species of Conservation Concern.* A joint project between the Sydney Catchment Authority and the Parks and Wildlife Division of the department of Environment and Conservation, Sydney.

Ehmann, H. (ed.) 1997. *Threatened frogs of New South Wales: Habitats, Status and Conservation.* Frog and Tadpoles Study Group of NSW, Sydney.

Gillespie, G. 2002. Impacts of sediment loads, tadpole density, and food type on the growth and development of tadpoles of the spotted tree frog *Litoria spenceri:* an in stream experiment. *Biological Conservation* **106**: 141-150.

Gillespie, G. and Hollis, G.J. 1996. Distribution and habitat of the spotted tree frog *Litoria spenceri* Dubois (Anura: Hylidae), and an assessment of the potential causes of population declines. *Wildlife Research* **23:** 49-75.

Goldingay, R. L. and Newell, D.A. 2005. Aspects of the population ecology of the green and golden bell frog *Litoria aurea* at the northern end of its range. *Australian Zoologist* **33:** 49-59.

Jones, D. and Morgan, G. 2002. *A Field Guide to Crustaceans of Australian Waters.*Second edition Reed New Holland.

Hero, J-M., Littlejohn, M. and Marantelli, G. 1991. A frogwatch fieldguide to the Victorian frogs. Victorian Department of Conservation and Environment, Melbourne.

Hero, J-M., Littlejohn, M., Gillespie, G., Lemckert, F., Robertson, P. and Littlejohn, M. 2002. *Litoria littlejohni.* Species profile on Amphibia web, http://elib.cs.berkely.edu/aw.

Lemckert, F. 2004. The biology and conservation status of the heath frog *Litoria littlejohni. Herpetofauna* **34**: 99-104.

Mahony, M. J. 1993. The status of frogs in the Watagan Mountains area, the central coast of New South Wales, Pp. 257-264 in *Herpetology in Australia. A Diverse Discipline,* edited by D. Lunney and D. Ayres. Royal Zoological Society of NSW, Mosman, NSW.

Morgan, L.A. and Buttemer, W. A. 1996. Predation by the non-native fish *Gambusia holbrooki* on small *Litoria aurea* and *L. dentata* tadpoles. *Australian Zoologist* **30:** 143-149.

Neilly, B. 2001. Report on the targeted and systematic survey of Barren Grounds Nature Reserve and Budderoo National Park for the vulnerable frog species *Litoria littlejohni,* the Heath Frog. Unpublished report prepared for the NSW NPWS.

NSW NPWS Threatened Species Management. 2001. Information Circular No. 6.Hygiene Protocol for the control of Diseases in Frogs. NPWS, Hurstville, Sydney.

Richards, S.J., McDonald, K.R and Alford, R.A. 1993. Declines and populations of Australia's endemic tropical rainforest frogs. *Pacific Conservation Biology* **1**: 66-77.

Thomas V., Gellie N. and Harrison T. 2000. Forest ecosystem classification and mapping for the southern Comprehensive Regional Assessment. NSW National Parks and Wildlife Service, Queanbeyan.

Tindall, D., Pennay, C., Tozer, M., Turner, K. and Keith, D. 2005. Native vegetation map report series No. 4 version 2.2 Araleun, Batemans Bay, Braidwood, Burragorang, Goulburn, Jervis Bay, Katoomba, Kiama, Moss Vale, Penrith, Port Hacking, Sydney, Taralga, Ulladulla and Wollongong 1:100 000 Mapsheets. Department of Environment and Conservation and Department of Infrastructure Planing and Natural Resources.

Tyler, M. J. 1989. *Australian Frogs.* Viking O'Neil, Victoria.

White, A. M., Whitford, R. W. and Mahony, M. J. 1994. A new species of *Litoria* (Anura: Hylidae) from eastern Australia. *Proceedings of the Linnean Society NSW.* **114**: 3-10.

White, A. W. and Pyke, G. H. 1996. Distribution and conservation status of the green and golden bell frog *Litoria aurea* in New South Wales. *Australian Zoologist* **30:** 177-89.